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No. 714

FLIGHT TESTS OF RETRACTABLE AILERONS ON
A HIGHLY TAPERED WING

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A HIGHLY TAPERED WING

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SUMMARY

A flight investigation was conducted to determine the lateral-control characteristics of retractable ailerons installed on a highly tapered wing. The effectiveness of the ailerons in producing roll was measured at various air speeds with full-span plain flaps both neutral and deflected 45°. The direction of the yawing moment created by the ailerons was also noted.

The lateral control provided by the retractable ailerons used in this investigation was approximately the same as that obtained with the plain ailerons of equal span with which the airplane was previously equipped. The amount of control available was found to be somewhat inadequate, apparently because of the rather short span of the ailerons (0.327 of the wing span). It is likely that, with an aileron span of from 0.50 to 0.60 of the wing span, a satisfactory degree of control would be obtained. With the full-span flaps deflected 45°, the rolling action of the ailerons was increased about 30 percent over that obtained with the flaps neutral at the same speed. The yawing moment produced by the ailerons was in the same sense as the rolling moment, i.e., right roll was accompanied by right yaw. Lag in the response of the rolling action to control application was not large enough to be noticed by the pilots. No appreciable control force was apparent to the pilots, which was considered somewhat undesirable. Minor modifications in the design of the ailerons, however, would probably correct this fault.

INTRODUCTION

With ailerons of the conventional type extending over a considerable portion of the wing trailing edge, it is

generally possible to use only partial-span flaps. The need for the greater effectiveness afforded by full-span flaps is increasing as airplane wing loadings increase and, as a result, considerable attention is being directed to the problem of developing lateral-control devices that will permit the use of full-span flaps.

One of the most promising of the lateral-control devices proposed thus far is the retractable aileron. This device has been tested both in flight (reference 1) and in the wind tunnel (reference 2) on rectangular wings with full-span flaps and was found to compare very favorably with conventional ailerons.

The present investigation was made to determine the characteristics of retractable ailerons when installed on a highly tapered wing. The effectiveness of the ailerons in producing roll was measured for abrupt full deflections at various air speeds, and the variation of rolling action with aileron displacement at constant air speed was determined. The initial yaw resulting from deflection of the ailerons was also measured. The tests were made with flaps both neutral and deflected,

APPARATUS

The airplane used in the present tests was a modified Fairchild 22, a small low-wing monoplane with a highly tapered wing. Figure 1 is a photograph of the airplane, and figure 2 is a sketch of the plan form of the wing. The pertinent dimensional characteristics of the wing are given in table I.

The wing was fitted with full-span plain flaps having a chord 0.23 of the wing chord over the inboard section and a chord 0.20 of the wing chord over the outboard section.

The retractable aileron is shown in figure 3. This aileron consisted of two curved aluminum-alloy plates tangent at their lower edges and separated at their upper edges by a filler block, as shown in figure 4. In the neutral position, the aileron was enclosed within the wing, the upper edge lying flush with the wing upper surface. When actuated, the aileron rotated out of the wing about an axis coincident with the center of curvature of its

forward surface. The opposite aileron retracted slightly into the wing by virtue of an extreme differential linkage system. The aileron had a span 0.327 of the wing span and, in the fully extended position, projected 0.105 of the wing chord above the wing upper surface. The differential motion of the aileron is given in figure 5.

The following standard N.A.C.A. recording instruments were used to obtain the necessary data: two angular-velocity recorders, one arranged to measure rolling velocity and the other to measure yawing velocity; a control-position recorder connected to the ailerons; an air-speed recorder; and a timer.

TESTS

The tests consisted in recording the angular velocities of roll and yaw, the position of the ailerons, and the air speed over a period of several seconds during which the control stick was moved abruptly to the right from its neutral position. The rudder was held neutral throughout the maneuver, which was started with the airplane in a steady glide. The duration of the records was sufficient to assure the attainment of maximum rolling velocity.

Records were taken for full aileron deflection at various air speeds between 70 and 100 miles per hour with the flaps neutral and between 58 and 75 miles per hour with the flaps down 45°. Tests were also made in which the ailerons were deflected to various positions between neutral and full deflection at given air speeds (70 and 100 miles per hour with the flaps neutral and 58 and 75 miles per hour with the flaps down) in order to determine whether or not the ailerons had any undesirable characteristics in the relation between rolling action and aileron deflection.

The maximum angular velocities of roll resulting from deflection of the ailerons were read directly from the records. Maximum rolling accelerations were determined by graphical differentiation, and the angles of bank attained 1 second after the initial movement of the ailerons were determined by mechanical integration of angular velocity-time curves. The rolling moment and the rolling-moment coefficients were evaluated from the data furnished by the records in accordance with the method described in reference 1.

Comparison of the time at which aileron movement was started with the time at which the rolling motion started provided a measure of the lag of rolling response to control application.

The yawing-velocity records were used only as a means of determining the direction of the initial yawing motion caused by the ailerons.

RESULTS AND DISCUSSION

The results of the tests of both the plain-wing (or flap-neutral) and the flap-down conditions are presented in figures 6 to 9. Figure 6 shows the variation with air speed of the maximum angular velocity and acceleration of roll resulting from full aileron deflection. In figure 7, the angle of roll attained in 1 second following abrupt full aileron deflection is plotted against air speed. The variation of rolling-moment coefficient with lift coefficient is given in figure 8. In figure 9, the variation of maximum angular velocity of roll with aileron deflection is shown at two air speeds for each wing condition.

The present retractable-aileron installation was generally considered by the pilots to be unsatisfactory owing to insufficiently powerful rolling action. The results derived from the instrument records confirmed this impression, particularly in the lower end of the speed range tested.

Unfortunately, there are no quantitative flight-test data for conventional ailerons on a highly tapered wing that are directly comparable with the results from the present retractable-aileron tests. Although the wing was equipped with 25-percent mean-chord plain ailerons prior to the installation of the retractable ailerons, the effectiveness of the plain ailerons in producing roll was not measured. Pilots' observations, however, indicated that there was little choice, as regards rolling effectiveness, between the plain and the retractable ailerons, which were of approximately the same span. It therefore appears that the inadequacy of the retractable ailerons used in this investigation was due to insufficient span rather than to any weakness peculiar to this type of aileron.

Calculations based on the results of the present tests

and using the data and the methods of reference 3 indicated that satisfactory control for the airplane tested would be provided if the retractable aileron span were increased to between 50 and 60 percent of the wing span. Very nearly the same span would probably also be required with plain ailerons. In the case of the retractable ailerons, there is no obvious objection to the use of almost any aileron span desired if suitable provisions are made in the wing design. With conventional ailerons, on the other hand, any increase in aileron span would generally result in the curtailment of flap span.

The aileron arrangement that has served hitherto as the standard of comparison for the Committee's flight research on lateral-control devices is the unsealed plain aileron having a chord 18 percent of the wing chord and extending along the entire span of a rectangular wing. The results of flight tests of this arrangement, which was found to provide satisfactory lateral control for an airplane of the type under consideration, are reported in reference 4. Comparison of the results from reference 4 with those for the plain-wing condition of the present tests revealed that, for a given speed at the low end of the speed-range tested, the maximum rolling acceleration produced by the retractable ailerons (fig. 6) was only 40 percent of that obtained with the standard ailerons. The moment of inertia of the tapered wing used in the present investigation, however, was about 25 percent greater than that of the standard rectangular wing so that, for the same moment of inertia, the difference in rolling acceleration would have been about 50 percent. The retractable ailerons gave 65 percent of the maximum angular velocity obtained with the standard plain ailerons. The angle of roll 1 second after control application (fig. 7) was, as would be expected, about half of that attained with the standard ailerons and about two-thirds of the value (15°) given in reference 3 as representing the minimum satisfactory degree of control for a light airplane.

The effectiveness of the retractable ailerons increased much more rapidly with increasing speed than that of the standard plain ailerons. Thus, at the highest speed tested, the difference in maximum rolling acceleration was reduced to about 20 percent. (With the same moment of inertia, the values for the two ailerons would be very nearly equal.) The maximum rolling velocity was 15 percent and the angle of roll attained in 1 second was 25 percent less than the values obtained with the standard plain ailerons.

The large variation in rolling effectiveness exhibited by the combination of retractable ailerons and tapered wing is more apparent in figure 8 where it is shown that, at the highest lift coefficient tested ($C_L = 1.2$), the rolling-moment coefficient was only half of that at the lowest lift coefficient ($C_L = 0.6$). For ailerons mounted on rectangular wings, on the other hand, the rolling-moment coefficient is, in general, relatively constant within the unstalled-flight range. The rolling-moment coefficient of the retractable ailerons was about half that of the standard plain ailerons at the highest lift coefficient but was slightly greater than that of the standard ailerons at the lowest lift coefficient.

The effect of a 45° deflection of the full-span plain flaps on the rolling action of the retractable ailerons for full deflection is shown in figures 6 to 8. The results plotted in these figures show that the flaps increase the effectiveness of the ailerons about 30 percent for a given air speed or lift coefficient. It will be noted that the rolling action at the lowest speed obtained with the flaps down was approximately the same as that obtained with the flaps neutral at the lowest speed for this condition. This result indicates that, for a wing and flap arrangement similar to the one used in this investigation, retractable ailerons designed to provide satisfactory control throughout the speed range for the plain-wing condition would probably be adequate in the lower speed range available with full-span flaps.

From the results presented in figure 9, it is believed that the relation between rolling action and aileron deflection is sufficiently close to direct proportionality to be satisfactory.

The existence of a lag of about one-tenth second in the response of rolling action to aileron displacement was detected from the instrument records. This lag, however, was not evident to the pilots; hence, it is probably not an objectionable feature.

The direction of the initial yawing motion (with respect to airplane axes) resulting from deflection of the ailerons was of the same sense as the roll for all the conditions tested.

It was anticipated that the sectional form of the aileron with its flat upper edge and eccentric rearward sur-

face (see fig. 4) would provide a small but definite aerodynamic hinge moment and, hence, some degree of "feel" in the control, but this expectation was not realized. The pilots reported that there was no appreciable stick force and little tendency for the stick to return to neutral. This lack of stick force, which appears to be the primary objection to the use of retractable ailerons on small airplanes, can be overcome by increasing the width of the upper edge of the aileron. Such a solution would have the added advantage of permitting the use of a lower hinge axis (possibly concealed within the wing) without a reduction in the effective height of the aileron when fully deflected.

CONCLUDING REMARKS

The retractable ailerons tested in this investigation gave approximately the same degree of control as the plain ailerons of equal span with which the airplane was previously equipped. The amount of control available with the retractable ailerons was not sufficient to be considered satisfactory owing, apparently, to their rather short span (0.327 of the wing span). With the aileron span increased to between 0.50 and 0.60 of the wing span, a satisfactory degree of control would probably be obtained.

The full-span flaps, when deflected 45° , increased the effectiveness of the ailerons at a given air speed about 30 percent over that with the flaps neutral.

For all conditions tested, the direction of the yawing moment (referred to airplane axes) due to the ailerons was in the same sense as the rolling moment, i.e., right aileron deflection resulted in right yaw.

Lag in the response of rolling action to control manipulation was too small to be noticed by the pilots and therefore was not objectionable.

The hinge moment of the ailerons was too light to provide any feel in the control stick, but this somewhat undesirable feature can be removed by minor modifications in the aileron design.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 1, 1939.

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2. Wenzinger, Carl J., and Bamber, Millard J.: Wind-Tunnel Tests of Three Lateral-Control Devices in Combination with a Full-Span Slotted Flap on an N.A.C.A. 23012 Airfoil. T.N. No. 659, N.A.C.A., 1938.
3. Weick, Fred E., and Jones, Robert T.: Résumé and Analysis of N.A.C.A. Lateral Control Research. T.R. No. 605, N.A.C.A., 1937.
4. Soulé, H. A., and Gracey, W.: Improvement of Aileron Effectiveness by the Prevention of Air Leakage through the Hinge Gap as Determined in Flight. T.N. No. 632, N.A.C.A., 1938.

TABLE I
CHARACTERISTICS OF THE MODIFIED
FAIRCHILD 22 AIRPLANE

Wing

Area (S)	114 sq. ft.
Span (b)	34 ft.
Root chord (c_r)	5 ft. 8 in.
Tip chord (c_t)	1 ft. 1-3/4 in.
Aspect ratio	10
Taper ratio	5
Wing section:	
At root	N.A.C.A. 23015
At tip	N.A.C.A. 23009
Dihedral angle	5-1/2°

Flap

	Inboard section	Outboard section
Type	Plain	Plain
Span (each side) . . .	2 ft. 9-1/2 in. . .	12 ft. 9 in.
Chord	0.23 c_w	0.20 c_w
Maximum deflection . .	45°	45°

Ailerons

Span (each)	5 ft. 6-3/4 in. (0.327 b/2)
Maximum deflection:	
Up	0.105 c_w
Down	0.028 c_w

Weight Data

Gross weight	1,720 lb.
Moment of inertia about longitudinal axis ..	884 slug-ft. ²



Figure 1.- The modified Fairchild-22 airplane, showing the full-span flaps.

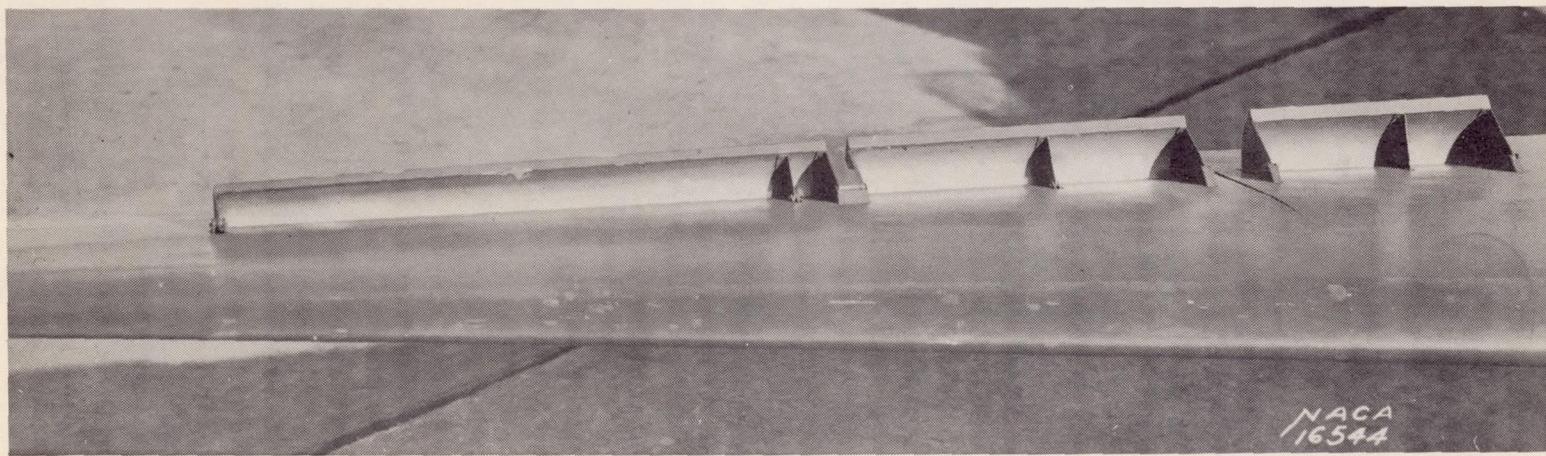


Figure 3.- Front view of the retractable ailerons in the fully extended position.

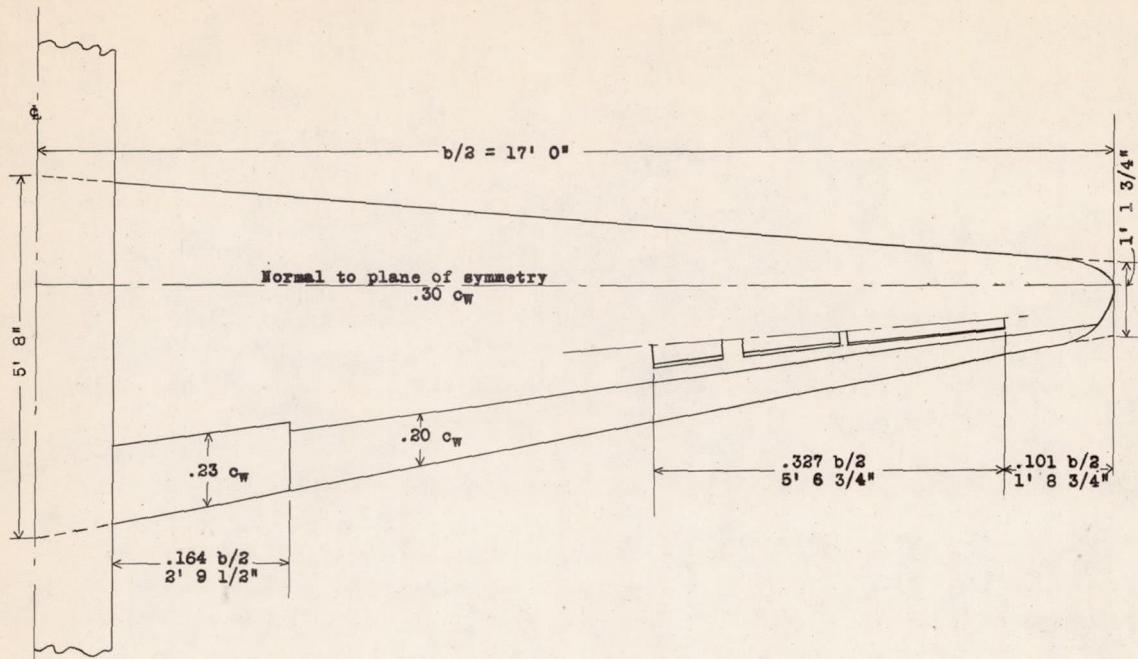


Figure 2.- Sketch of plan form of wing of modified Fairchild 22 airplane.

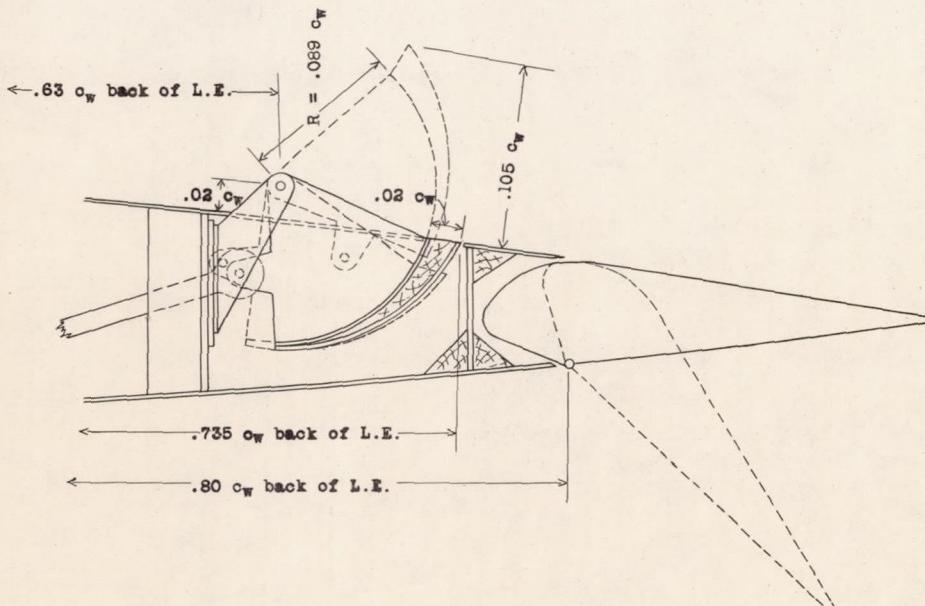


Figure 4.- Section view of retractable ailerons and flaps as installed on modified Fairchild 22 airplane.

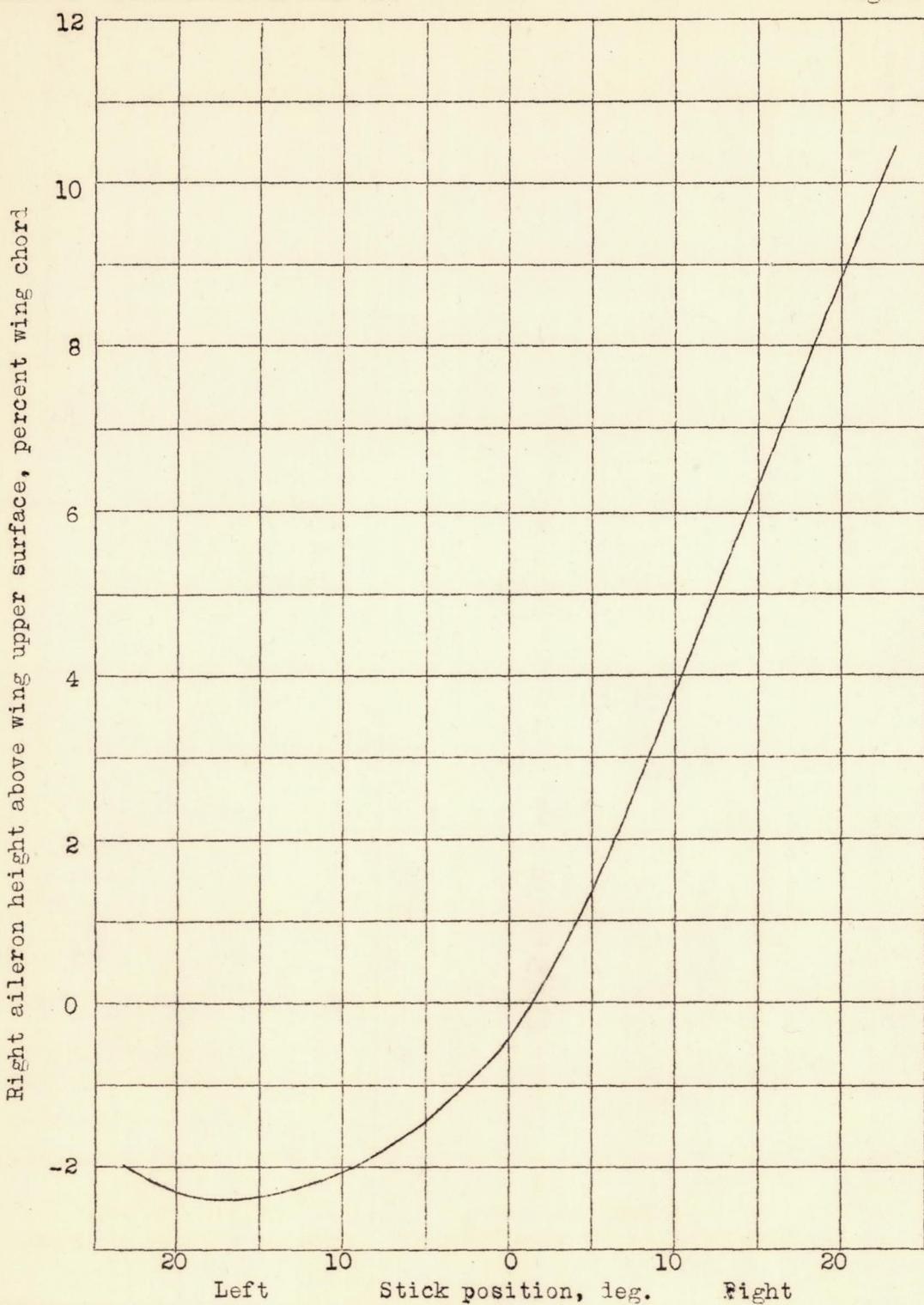


Figure 5.- Differential motion of retractable ailerons on modified Fairchild 22 airplane.

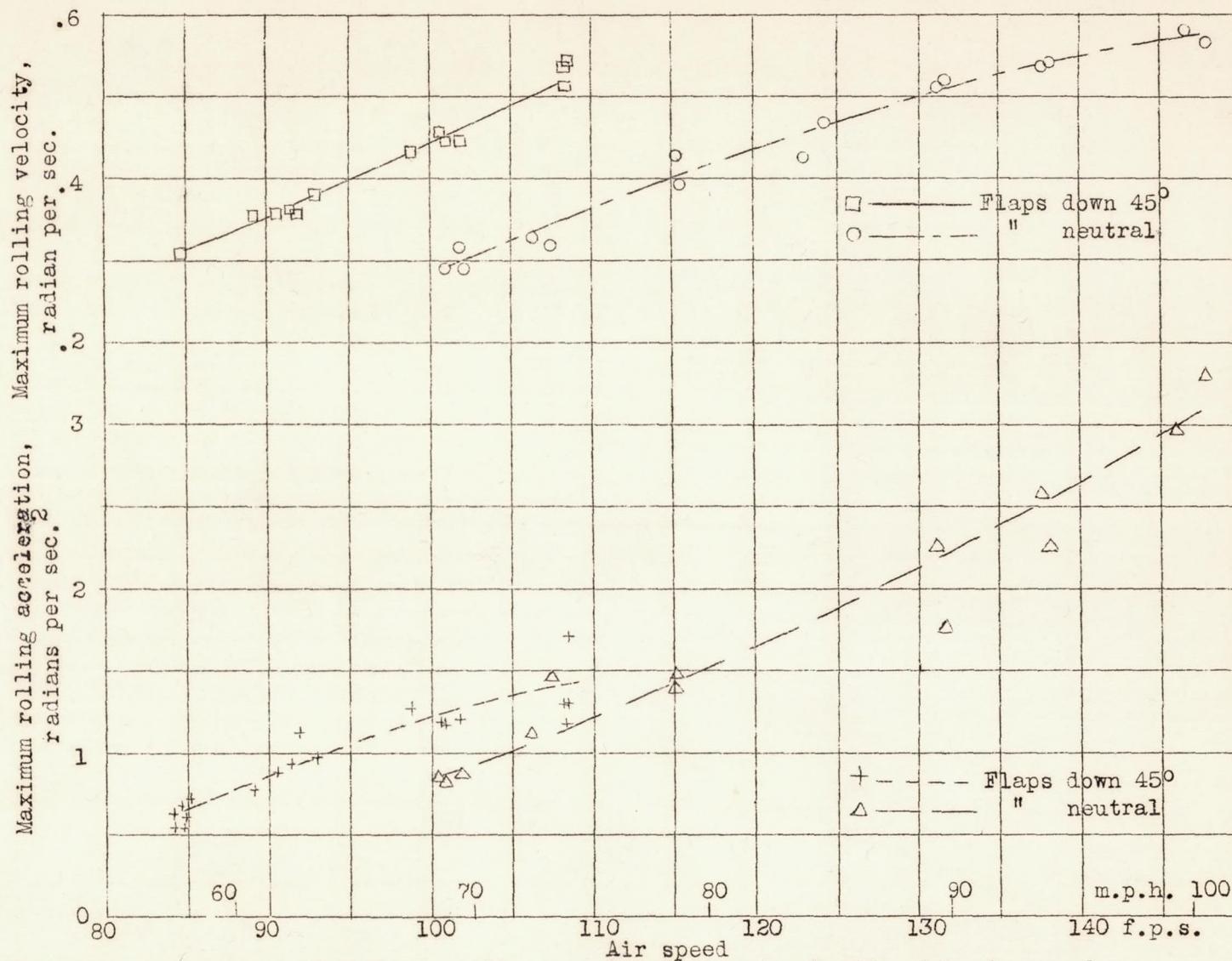


Figure 6.— Variation of maximum rolling acceleration and velocity with air speed.
Retractable ailerons fully deflected; modified Fairchild 22 airplane.

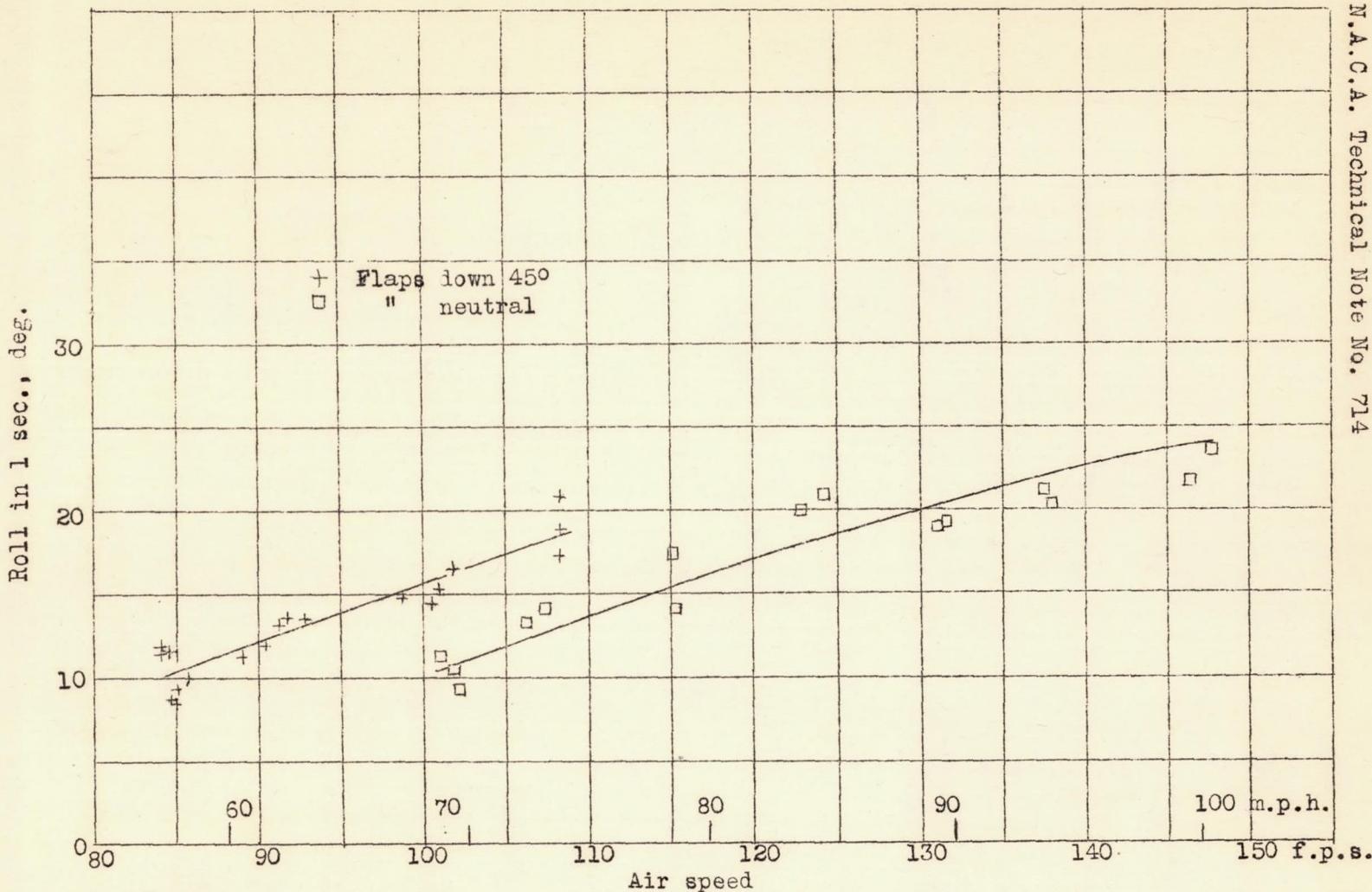


Figure 7.- Variation of angle of roll attained in 1 second with air speed. Retractable ailerons fully deflected; modified Fairchild 22 airplane.

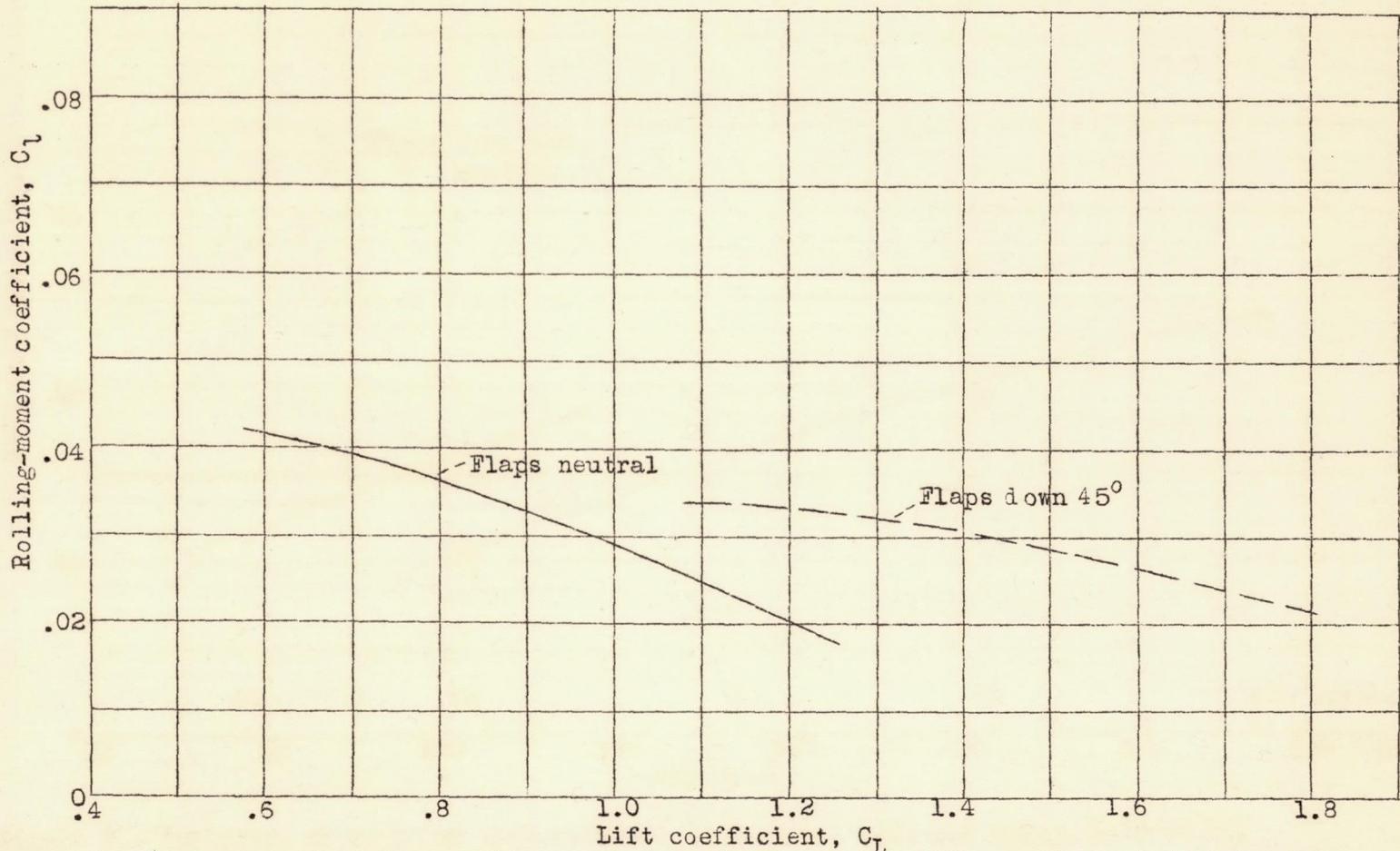


Figure 8.- Variation of maximum rolling-moment coefficient with lift coefficient, Retractable ailerons fully deflected; modified Fairchild 22 airplane.

